Conservation Agriculture and Soil Carbon Sequestration; Summary of a Critical Review

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Introduction

Conservation agriculture (CA), based on minimum tillage, crop residue retention, and crop rotations, has been proposed as an alternative system that combines benefits for the farmer with advantages for the society.

Figure 1: Conservation agriculture with maize after wheat in untilled soil with the residue of the previous crop retained.

Carbon sequestration, the C and N cycle

This poster is a summary of an extensive review of the potential impact of CA on C sequestration published in Critical Reviews in Plant Sciences (Govaerts et al., 2009). The C and N cycle are closely linked in agricultural ecosystems (see Figure 3). To evaluate the C sequestration capacity of farming practices, their influence on emissions from farming activities should be considered together with their influence on soil C stocks.

Carbon levels in soil are determined by the balance of inputs, such as crop residues, organic amendments, and C losses through organic matter decomposition. Upon cultivation of previously untilled soils, this balance is disrupted and generally 20% to 40% of the soil C is lost, most of it within the first few years following initial cultivation. Afterwards, the rate of decrease levels off, and some decades later a new management-dependent soil humus level is attained (see Figure 4).

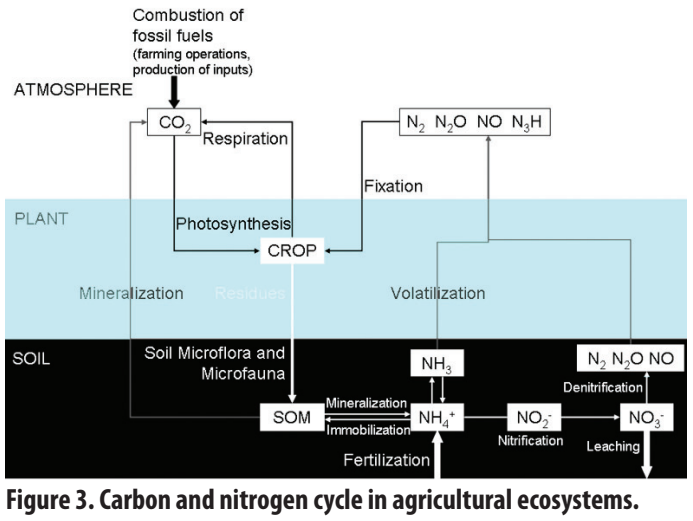

Figure 3. Carbon and nitrogen cycle in agricultural ecosystems.

Figure 2: Conservation agriculture is applicable to a wide range of farming situations, from (a) commercial irrigated farmers in northern Mexico to (b) small-holder farmers in the rainfed drought prone highlands of Ethiopia.

Carbon sequestration and conservation agriculture

Some of the already existing reviews on the influence of agriculture and management on C sequestration made by West and Post (2002), Jarecki and Lal (2003), VandenBygaart et al. (2003), and Blanco-Canqui and Lal (2008) were used as a basis and completed through further literature search along with other sources. It should be noted that only results from measurements at least 30 cm deep and after at least 5 years of continuous practice were considered. The largest farming emission reductions from CA are from the reduction of tillage operations.

The soil C case study results are not conclusive. In 7 of the 78 cases withheld, the soil C stock was lower in zero tillage compared to conventional tillage, in 40 cases it was higher, and in 31 of the cases there was no significant difference. The mechanisms that govern the balance between increased or no sequestration after conversion to zero tillage are not clear, although some factors can be distinguished e.g. root development and rhizodeposits, baseline soil C content, bulk density and porosity, climate, landscape position, and erosion/deposition history. Altering crop rotation can influence soil C stocks by changing quantity and quality of organic matter input.

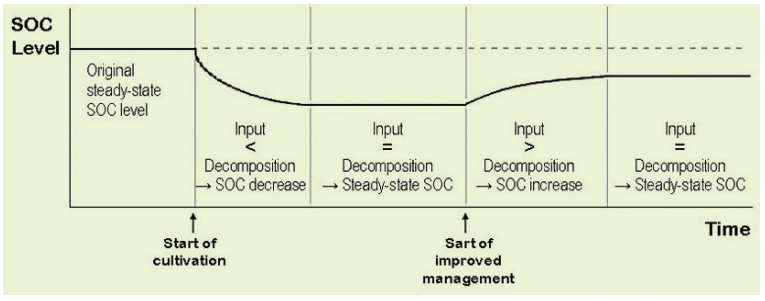

Figure 4. Long-term soil organic carbon level changes depending on carbon input and decomposition.

Conclusions

1. CA is a cropping system characterized by short-term maximization of crop production as well as by potential long-term sustainability (i.e. carbon storage) at micro-site (i.e. soil aggregation studies) and farm level (i.e. yield analysis, profitability).
2. Concerning the potential of CA as a strategy for C sequestration, important gaps still need to be covered. There is a need for the development of an international network that connects different CA research sites in a working network of excellence, so that the underlying mechanisms of C storage as influenced by CA can be revealed.
3. Even if carbon sequestration is questionable in some areas and some cropping systems, CA remains an important technology that improves soil processes, controls soil erosion, and reduces tillage-related production costs. These are sufficient reasons for CA promotion. Global food security, global environmental preservation, and farmer-level increased livelihoods should be the main goals of a sustainable farming system.

Further detail

Govaerts, B., Verhulst, N., Castellanos-Navarrete, A., Sayre, K.D., Dixon, J., Dendooven, L. 2009. Conservation Agriculture and Soil Carbon Sequestration; Between Myth and Farmer Reality. Critical Reviews in Plant Science, 28 (3), 97-122.